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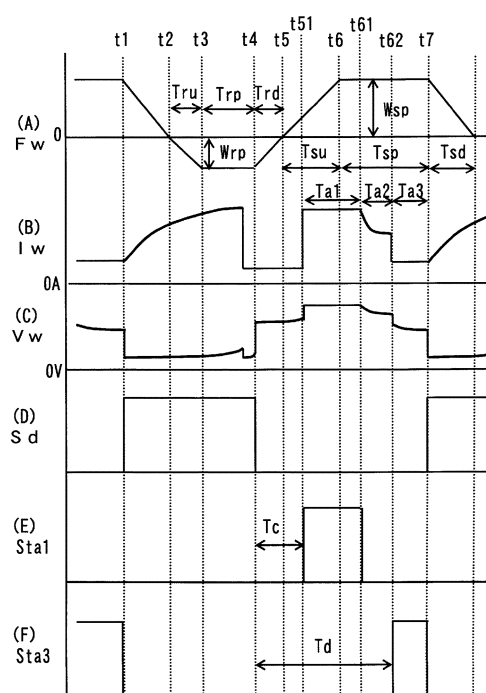
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(54) **ARC WELDING CONTROL METHOD**

(57) To stabilize a welding state when a base material is a galvanized steel sheet in a welding method in which a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period. In an arc welding control method for controlling welding in which a material of a base material is a galvanized steel sheet, a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period, and a short circuit period and an arc period are repeated, during the arc period, a first arc period Ta1 during which a first arc current Ia1 is applied, a second arc period Ta2 during which a second arc current Ia2 is applied, and a third arc period Ta3 during which a third arc current Ia3 is applied are switched over time, and it is controlled so as to be Ia1 > Ia2 > Ia3. Constant voltage control is performed during the second arc period Ta2, and constant current control is performed during the first arc period Ta1. A value of the first arc period Ta1 and/or the first arc current Ia1 is changed according to a zinc deposition amount per unit area of the base material.

FIG. 2



Description

Technical Field

[0001] The present invention relates to an arc welding control method for controlling welding in which a material of a base material is a galvanized steel sheet, a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period, a short circuit period and an arc period are repeated.

Background Art

[0002] In general consumable electrode-type arc welding, the welding is performed by feeding a welding wire as a consumable electrode at a constant speed, and generating an arc between the welding wire and a base material. In the consumable electrode-type arc welding, a welding state of alternately repeating the welding wire and the base material in a short circuit period and an arc period is often obtained.

[0003] In order to further improve the welding quality, a welding method of periodically repeating forward feed and reverse feed of a welding wire has been proposed (see, for example, Patent Literature 1).

Prior Art Literature

Patent Literature

[0004] Patent Literature 1: JP-T-2008-531283

Summary of Invention

Problem to be Solved by the Invention

[0005] In arc welding for the galvanized steel sheet, during the welding, zinc on the surface of the base material turns into vapor due to the arc heat, which is ejected as gas from a molten pool, resulting in a phenomenon that the welding state is unstable. In addition, the gas ejection phenomenon is prominent in arc welding in which the feed speed of the welding wire is alternately switched between the forward feed period and the reverse feed period, as compared with general arc welding in which the feed speed is constant.

[0006] Accordingly, the present invention is to provide an arc welding control method capable of stabilizing a welding state and reducing a spatter generation amount in arc welding in which the material of a base material is a galvanized steel sheet and a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period.

Means for Solving the Problem

[0007] An arc welding control method according to the present disclosure relates to

an arc welding control method for controlling welding in which a material of a base material is a galvanized steel sheet, a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period, and a short circuit period and an arc period are repeated, wherein

during the arc period, a first arc period during which a first arc current I_{a1} is applied, a second arc period during which a second arc current I_{a2} is applied, and a third arc period during which a third arc current I_{a3} is applied are switched over time, and it is controlled so as to be $I_{a1} > I_{a2} > I_{a3}$.

[0008] In the arc welding control method according to the present disclosure, constant voltage control is performed during the second arc period.

[0009] In the arc welding control method according to the present disclosure, constant current control is performed during the first arc period.

[0010] In the arc welding control method according to the present disclosure, a value of the first arc period and/or the first arc current is set to a value such that zinc vapor does not remain in a molten pool after being discharged from the molten pool.

[0011] In the arc welding control method according to the present disclosure, the value of the first arc period and/or the first arc current I_{a1} changes according to a zinc deposition amount per unit area of the base material.

[0012] In the arc welding control method according to the present disclosure, a waveform parameter of the feed speed is set so that an average value of repetition frequencies of the forward feed period and the reverse feed period is in a range of 70 Hz to 90 Hz.

[0013] In the arc welding control method according to the present disclosure, the waveform parameter is at least a forward feed peak value and a reverse feed peak value.

[0014] In the arc welding control method according to the present disclosure, the waveform parameter is set so that the average value of the repetition frequencies lowers as the zinc deposition amount per unit area of the base material increases.

Effects of Invention

[0015] According to the present invention, a welding state can be stabilized and a spatter generation amount can be reduced in arc welding in which the material of a base material is a galvanized steel sheet and a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period.

Brief Description of Drawings

[0016]

Fig. 1 is a block diagram of a welding power source for performing an arc welding control method according to a first embodiment of the present invention.

Fig. 2 is a timing chart of each signal in the welding power source of Fig. 1 showing the arc welding control method according to the first embodiment of the present invention.

Fig. 3 is a block diagram of a welding power source for performing an arc welding control method according to a second embodiment of the present invention.

Fig. 4 is a block diagram of a welding power source for performing an arc welding control method according to a third embodiment of the present invention.

Embodiments for Carrying Out the Invention

[0017] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[First Embodiment]

[0018] Fig. 1 is a block diagram of a welding power source for performing an arc welding control method according to a first embodiment of the present invention. Hereinafter, each block will be described below with reference to Fig. 1.

[0019] A power source main circuit PM receives an output from a 3-phase 200 V commercial power source (not shown) or the like, performs output control by inverter control according to an error amplification signal Ea to be described later, and outputs an output voltage E. The power source main circuit PM includes a primary rectifier for rectifying the commercial power source, a smoothing capacitor for smoothing a rectified direct current, an inverter circuit driven by the error amplification signal Ea that converts the smoothed direct current into a high-frequency alternating current, a high-frequency transformer for stepping down the high-frequency alternating current to a voltage value suitable for welding, and a secondary rectifier for rectifying the step-down high-frequency alternating current into a direct current, which are not shown.

[0020] A reactor WL smooths the output voltage E. The inductance value of the reactor WL is, for example, 100 μ H.

[0021] A feed motor WM receives a feed control signal Fc to be described later as an input and alternately repeats forward feed and reverse feed to feed a welding wire 1 at a feed speed Fw. A motor with fast transient response is used as the feed motor WM. In order to increase the change rate of the feed speed Fw of the welding wire 1 and speed up the reversal of the feed direction, the feed motor WM may be installed near a tip of a welding torch 4. In addition, two feed motors WM may be used to form a push-pull type feed system.

[0022] The welding wire 1 is fed inside the welding torch 4 by the rotation of a feed roll 5 coupled to the feed motor WM, and an arc 3 is generated between the welding wire 1 and a base material 2. A welding voltage Vw is applied between the power source tip (not shown) in the welding torch 4 and the base material 2, and thus a

welding current Iw is applied. The material of the base material 2 is a galvanized steel sheet.

[0023] An output voltage setting circuit ER outputs a predetermined output voltage setting signal Er. An output voltage detection circuit ED detects and smoothes the output voltage E and outputs an output voltage detection signal Ed.

[0024] A voltage error amplification circuit EV receives the output voltage setting signal Er and the output voltage detection signal Ed as inputs, amplifies an error between the output voltage setting signal Er(+) and the output voltage detection signal Ed(-), and outputs a voltage error amplification signal Ev.

[0025] A current detection circuit ID detects the welding current Iw and outputs a current detection signal Id. A voltage detection circuit VD detects the welding voltage Vw and outputs a voltage detection signal Vd. A short circuit determination circuit SD receives the voltage detection signal Vd as an input, and outputs a short circuit determination signal Sd which is determined to be at a short circuit period and at a high level when the value of the voltage detection signal Vd is less than a predetermined short circuit determination value (about 10 V), and is determined to be at an arc period and at a low level when the value of the voltage detection signal Vd is equal to or larger than the predetermined short circuit determination value.

[0026] A forward feed acceleration period setting circuit TSUR outputs a predetermined forward feed acceleration period setting signal Tsur.

[0027] A forward feed deceleration period setting circuit TSDR outputs a predetermined forward feed deceleration period setting signal Tsdr.

[0028] A reverse feed acceleration period setting circuit TRUR outputs a predetermined reverse feed acceleration period setting signal Trur.

[0029] A reverse feed deceleration period setting circuit TRDR outputs a predetermined reverse feed deceleration period setting signal Trdr.

[0030] A forward feed peak value setting circuit WSR outputs a predetermined forward feed peak value setting signal Wsr.

[0031] A reverse feed peak value setting circuit WRR outputs a predetermined reverse feed peak value setting signal Wrr.

[0032] A feed speed setting circuit FR receives the forward feed acceleration period setting signal Tsur, the forward feed deceleration period setting signal Tsdr, the reverse feed acceleration period setting signal Trur, the reverse feed deceleration period setting signal Trdr, the forward feed peak value setting signal Wsr, the reverse feed peak value setting signal Wrr and the short circuit determination signal Sd as inputs, and outputs a feed speed pattern generated by the following process as a feed speed setting signal Fr. When the feed speed setting signal Fr is 0 or more, it becomes a forward feed period, and when the feed speed setting signal Fr is less than 0, it becomes a reverse feed period.

- 1) During a forward feed acceleration period T_{su} determined by the forward feed acceleration period setting signal T_{sur} , a feed speed setting signal F_r which is linearly accelerated from 0 to a forward feed peak value W_{sp} , i.e., a positive value, determined by the forward feed peak value setting signal W_{sr} is output.
- 2) Then, during a forward feed peak period T_{sp} , a feed speed setting signal F_r for maintaining the forward feed peak value W_{sp} is output.
- 3) When the short circuit determination signal S_d changes from a low level (arc period) to a high level (short circuit period), the period is shifted to a forward feed deceleration period T_{sd} determined by the forward feed deceleration period setting signal T_{sdr} , and a feed speed setting signal F_r which is linearly decelerated from the forward feed peak value W_{sp} to 0 is output.
- 4) Then, during a reverse feed acceleration period T_{ru} determined by the reverse feed acceleration period setting signal T_{rur} , a feed speed setting signal F_r which is linearly accelerated from 0 to a reverse feed peak value W_{rp} , i.e., a negative value, determined by the reverse feed peak value setting signal W_{rr} is output.
- 5) Then, during a reverse feed peak period T_{rp} , a feed speed setting signal F_r for maintaining the reverse feed peak value W_{rp} is output.
- 6) When the short circuit determination signal S_d changes from a high level (short circuit period) to a low level (arc period), the period is shifted to a reverse feed deceleration period T_{rd} determined by the reverse feed deceleration period setting signal T_{rdr} , and a feed speed setting signal F_r which is linearly decelerated from the reverse feed peak value W_{rp} to 0 is output.
- 7) By repeating the steps 1) to 6), the feed speed setting signal F_r of a feed pattern changing into a positive or negative trapezoidal wave is generated.

[0033] A feed control circuit FC receives the feed speed setting signal F_r as an input and outputs a feed control signal F_c for feeding the welding wire 1 at a feed speed F_w equivalent to the value of the feed speed setting signal F_r to the feed motor WM.

[0034] A current-limiting resistor R is inserted between the reactor WL and the welding torch 4. The value of the current-limiting resistor R is set to a value (about 0.5 Ω to 3 Ω) that is 10 times or more larger than a short circuit load (about 0.01 Ω to 0.03 Ω). When the current-limiting resistor is inserted in the current path, the energy stored in the reactor WL and a reactor of the external cable is rapidly discharged.

[0035] A transistor TR is connected in parallel to the current-limiting resistor R and is controlled to be turned on or off according to a drive signal Dr to be described later.

[0036] A constriction detection circuit ND receives the short circuit determination signal S_d , the voltage detec-

tion signal V_d and the current detection signal I_d as inputs, and outputs a constriction detection signal N_d , which is at a high level when it is determined that a formation state of the constriction has reached a reference state when a voltage rise value of the voltage detection signal V_d at a time when the short circuit determination signal S_d is at a high level (short circuit period) reaches a reference value, and which is at a low level at the time when the short circuit determination signal S_d changes to be at a low level (arc period). In addition, the constriction detection signal N_d may be changed to be at a high level when the differential value of the voltage detection signal V_d at a time when the short circuit period reaches the corresponding reference value. Further, a value of the voltage detection signal V_d is divided by a value of the current detection signal I_d to calculate a resistance value of the droplet and at a time when the differential value of the resistance value reaches the corresponding reference value, the constriction detection signal N_d may be set to be at a high level.

[0037] A low level current setting circuit ILR outputs a predetermined low level current setting signal I_{lr} . A current comparison circuit CM receives the low level current setting signal I_{lr} and the current detection signal I_d as inputs and outputs a current comparison signal C_m which is at a high level when $I_d < I_{lr}$ and at a low level when $I_d \geq I_{lr}$.

[0038] A drive circuit DR receives the current comparison signal C_m and the constriction detection signal N_d as inputs, and outputs the drive signal Dr, which changes to be at a low level when the constriction detection signal N_d changes to be at a high level and thereafter changes to be at a high level when the current comparison signal C_m changes to be at a high level, to a base terminal of the transistor TR. Therefore, when the constriction is detected, the drive signal Dr changes to be at a low level, the transistor TR is turned off, and the current-limiting resistor R is inserted in the current path, so that the welding current I_w for passing the short circuit load decreases rapidly. Further, when the value of the rapidly decreased welding current I_w decreases to the value of the low level current setting signal I_{lr} , the drive signal Dr changes to be at a high level and the transistor TR is turned on, so that the current-limiting resistor R is short-circuited and returns to a normal state.

[0039] A first arc period setting circuit TA1R outputs a predetermined first arc period setting signal T_{alr} . A first arc period circuit STA1 receives the short circuit determination signal S_d and the first arc period setting signal T_{alr} as inputs, and outputs a first arc period signal St_{a1} which changes to be at a high level during a first arc period T_{a1} predetermined by the first arc period setting signal T_{alr} from a time when a predetermined delay period T_c elapses after the short circuit determination signal S_d changes to be at a low level (arc period).

[0040] A first arc current setting circuit IA1R outputs a predetermined first arc current setting signal I_{a1r} .

[0041] A third arc period circuit STA3 receives the short

circuit determination signal Sd as an input, and outputs a third arc period signal Sta3 which changes to be at a high level at a time when a predetermined current drop time Td elapses from a time when the short circuit determination signal Sd changes to be at a low level (arc period), and thereafter changes to be at a low level when the short circuit determination signal Sd changes to be at a high level (short circuit period).

[0042] A third arc current setting circuit IA3R outputs a predetermined third arc current setting signal Ia3r.

[0043] A current control setting circuit ICR receives the short circuit determination signal Sd, the low-level current setting signal Ilr, the constriction detection signal Nd, the first arc period signal Sta1, the third arc period signal Sta3, the first arc current setting signal Ia1r, and the third arc current setting signal Ia3r as inputs, and outputs a current control setting signal Icr by performing the following process.

1) During the delay period from the time when the short circuit determination signal Sd changes to be at a low level (arc period) until the first arc period signal Sta1 changes to be at a high level, a current control setting signal Icr having a value of the low-level current setting signal Ilr is output.

2) When the first arc period signal Sta1 is at a high level (first arc period), a current control setting signal Icr which becomes the first arc current setting signal Ia1r is output.

3) During a period (the second arc period and the third arc period) from a time when the first arc period signal Sta1 changes to be at a low level until a time when the third arc period signal Sta3 changes to be at a low level, a current control setting signal Icr which becomes the third arc current setting signal Ia3r is output.

4) When the short circuit determination signal Sd changes to be at a high level (short circuit period), a current control setting signal Icr is output, which becomes a predetermined initial current setting value during a predetermined initial period, and thereafter increases to a predetermined short circuit peak setting value and maintains this value during a predetermined short circuit inclination.

5) Thereafter, when the constriction detection signal Nd changes to be at a high level, a current control setting signal Icr having a value of the low-level current setting signal Ilr is output.

[0044] A current error amplification circuit EI receives the current control setting signal Icr and the current detection signal Id as inputs, amplifies an error between the current control setting signal Icr(+) and the current detection signal Id(-), and outputs a current error amplification signal Ei.

[0045] A power source characteristic switching circuit SW receives the current error amplification signal Ei, the voltage error amplification signal Ev, the first arc period

signal Sta1, and the third arc period signal Sta3 as inputs, and outputs an error amplification signal Ea by performing the following process.

1) During a second arc period Ta2 from the first arc period signal Sta1 changes to be at a low level until the third arc period signal Sta3 changes to be at a high level, the voltage error amplification signal Ev is output as the error amplification signal Ea.

2) During other periods, the current error amplification signal Ei is outputs as the error amplification signal Ea.

[0046] With this circuit, the characteristic of the welding power source becomes a constant current characteristic during the short circuit period, the delay period, the first arc period Ta1 and the third arc period Ta3, and becomes a constant voltage characteristic during the second arc period Ta2.

[0047] Fig. 2 is a timing chart of each signal in the welding power source of Fig. 1 showing the arc welding control method according to the first embodiment of the present invention. (A) of Fig. 2 shows a time change of the feed speed Fw with time, (B) of Fig. 2 shows the change of the welding current Iw with time, (C) of Fig. 2 shows the change of the welding voltage Vw with time, (D) of Fig. 2 shows the change of the short circuit determination signal Sd with time, (E) of Fig. 2 shows the change of the first arc period signal Sta1 with time, and (F) of Fig. 2 shows the change of the third arc period signal Sta3 with time. Hereinafter, the operation of each signal will be described below with reference to Fig. 2.

[0048] The feed speed Fw shown in (A) of Fig. 2 is controlled to the value of the feed speed setting signal Fr output from the feed speed setting circuit FR of Fig. 1. The feed speed Fw includes the forward feed acceleration period Tsu determined by the forward feed acceleration period setting signal Tsur of Fig. 1, the forward feed peak period Tsp continuing until a short circuit occurs, the forward feed deceleration period Tsd determined by the forward feed deceleration period setting signal Tsdr of Fig. 1, the reverse feed acceleration period Tru determined by the reverse feed acceleration period setting signal Trur of Fig. 1, the reverse feed peak period Trp continuing until an arc occurs, and the reverse feed deceleration period Trd determined by the reverse feed deceleration period setting signal Trdr of Fig. 1. Further, the forward feed peak value Wsp is determined by the forward feed peak value setting signal Wsr of Fig. 1, and the reverse feed peak value Wrp is determined by the reverse feed peak value setting signal Wrr of Fig. 1. As a result, the feed speed setting signal Fr is a feed pattern changing into a positive or negative substantially trapezoidal wave shape.

[Operation during Short Circuit Period from Time Points t1 to t4]

[0049] When a short circuit occurs at a time point t1 during the forward feed peak period Tsp, the welding voltage Vw rapidly decreases to a short-circuit voltage value of several volts as shown in (C) of Fig. 2, so that the short circuit determination signal Sd changes to be at a high level (short circuit period) as shown in (D) of Fig. 2. In response to this, the period is shifted to a predetermined forward feed deceleration period Tsd from time points t1 to t2, and the feed speed Fw decelerates from the forward feed peak value Wsp to 0, as shown in (A) of Fig. 2. For example, the forward feed deceleration period Tsd is set to be 1 ms.

[0050] As shown in (A) of Fig. 2, the feed speed Fw enters a predetermined reverse feed acceleration period Tru from time points t2 to t3, and accelerates from 0 to the reverse feed peak value Wrp. During this period, the short circuit period continues. For example, the reverse feed acceleration period Tru is set to be 1 ms.

[0051] When the reverse feed acceleration period Tru ends at the time point t3, the feed speed Fw enters the reverse feed peak period Trp and becomes the reverse feed peak value Wrp, as shown in (A) of Fig. 2. The reverse feed peak period Trp continues until an arc occurs at a time point t4. Therefore, the time period from time points t1 to t4 is a short circuit period. The reverse feed peak period Trp is not a predetermined value, and is about 4 ms. For example, the reverse feed peak value Wrp is set to be -20 m/min to -50 m/min.

[0052] As shown in (B) of Fig. 2, the welding current Iw during the short circuit period from the time points t1 to t4 is a predetermined initial current value during the predetermined initial period. Thereafter, the welding current Iw increases to the predetermined short circuit peak value and maintains this value during the predetermined short circuit inclination.

[0053] As shown in (C) of Fig. 2, the welding voltage Vw increases when the welding current Iw becomes the short circuit peak value. This is because a constriction is gradually formed in the droplet at the tip of the welding wire 1 due to the reverse feed of the welding wire 1 and the action of the pinching force caused by the welding current Iw.

[0054] Thereafter, when the voltage rise value of the welding voltage Vw reaches the reference value, it is determined that the formation state of the constriction has reached the reference state, and the constriction detection signal Nd in Fig. 1 changes to be at a high level.

[0055] In response to the constriction detection signal Nd changing to be at a high level, the drive signal Dr of Fig. 1 changes to be at a low level, so that the transistor TR of Fig. 1 is turned off, and the current-limiting resistor R of Fig. 1 is inserted in the current path. At the same time, the current control setting signal Icr of Fig. 1 decreases to the value of the low-level current setting signal Ilr. Thus, as shown in (B) of Fig. 2, the welding current

Iw rapidly decreases from the short circuit peak value to a low-level current value. Further, when welding current Iw decreases to the low-level current value, the drive signal Dr returns to be at a high level, so that the transistor TR is turned on and the current-limiting resistor R is short-circuited. As shown in (B) of Fig. 2, since the current control setting signal Icr remains the low level current setting signal Ilr, the welding current Iw maintains the low-level current value until a predetermined delay period Tc elapses after the arc is regenerated. Therefore, the transistor TR is turned off only during the period from when the constriction detection signal Nd changes to be at a high level until the welding current Iw decreases to the low-level current value. As shown in (C) of Fig. 2, the welding voltage Vw rapidly increases after temporarily decreasing since the welding current Iw decreases. Each of the above parameters is set to, for example, the following value. Initial current = 40 A, initial period = 0.5 ms, short circuit inclination = 2 ms, short circuit peak value = 400 A, low-level current value = 50 A, delay period Tc = 1 ms.

[Operation during Arc Period from Time Points t4 to t7]

[0056] When the constriction forms due to the reverse feed of the welding wire and the pinch force caused by the application of the welding current Iw and an arc is generated at the time point t4, the welding voltage Vw rapidly increases to an arc voltage value of several tens of volts, as shown in (C) of Fig. 2. Therefore, the short circuit determination signal Sd changes to be at a low level (arc period), as shown in (D) of Fig. 2. In response to this, the period is shifted to a predetermined reverse feed deceleration period Trd from time points t4 to t5, and the feed speed Fw decelerates from the reverse feed peak value Wrp to 0, as shown in (A) of Fig. 2.

[0057] When the reverse feed deceleration period Trd ends at the time point t5, the period is shifted to a predetermined forward feed acceleration period Tsu from time points t5 to t6. As shown in (A) of Fig. 2, during the forward feed acceleration period Tsu, the feed speed Fw is accelerated from 0 to the forward feed peak value Wsp. During this period, the arc period continues. For example, the forward feed acceleration period Tsu is set to be 1 ms.

[0058] When the forward feed acceleration period Tsu ends at the time point t6, the feed speed Fw enters the forward feed peak period Tsp and becomes the forward feed peak value Wsp as shown in (A) of Fig. 2. During this period, the arc period also continues. The forward feed peak period Tsp continues until an arc occurs at a time point t7. Therefore, the time period from time points t4 to t7 is an arc period. When a short circuit occurs, the operation returns to the operation at the time point t1. The forward feed peak period Tsp is not a predetermined value, and is about 5 ms. For example, the forward feed peak value Wsp is set to be 20 m/min to 50 m/min.

[0059] When an arc occurs at time point t4, the welding

voltage V_w rapidly increases to an arc voltage value of several tens of Volts, as shown in (C) of Fig. 2. As shown in (B) of Fig. 2, the welding current I_w continues the low-level current value during the delay period T_c from the time point t_4 . This is because when the current value increases immediately after the arc is generated, the reverse feed of the welding wire and the melting of the welding wire due to the welding current are added together, the arc length may rapidly increase and the welding state may be unstable.

[0060] When the delay period T_c ends at the time point t_{51} during the forward feed acceleration period T_{su} , the first arc period signal $Sta1$ changes to be at a high level and shifts to the predetermined first arc period $Ta1$ at time points t_{51} to t_{61} , as shown in (E) of Fig. 2. The constant current control is continued during the first arc period $Ta1$, and a predetermined first arc current $Ia1$ determined by the first arc current setting signal $Ia1r$ in Fig. 1 is applied, as shown in (B) of Fig. 2. As shown in (B) of Fig. 2, the welding voltage V_w is a value determined by the current value and the arc load, which is a large value. For example, the first arc period $Ta1$ is set to be about 1 ms to 2 ms, and the first arc current $Ia1$ is set to be about 300 A to 500 A.

[0061] When a predetermined current drop time T_d has elapsed at the time point t_{62} from the time point t_4 when the arc is generated, the third arc period signal $Sta3$ changes to be at a high level as shown in (F) of Fig. 2. A period from time points t_{61} to t_{62} is a second arc period $Ta2$. The constant voltage control is performed during the second arc period $Ta2$. As shown in (B) of Fig. 2, the second arc current $Ia2$ varies depending on the arc load, and has a value smaller than the first arc current $Ia1$ and larger than the third arc current $Ia3$. That is, the output control is performed so as to be $Ia1 > Ia2 > Ia3$. As shown in (C) of Fig. 2, the welding voltage V_w is controlled to a predetermined value by the constant voltage control and becomes an intermediate value between the voltage value of the first arc period $Ta1$ and the voltage value of the third arc period $Ta3$. The second arc period $Ta2$ is not a predetermined value, and is about 3 ms to 6 ms.

[0062] The third arc period $Ta3$ is a period from the time point t_{62} when the third arc period signal $Sta3$ changes to be at a high level to the time point t_7 when a short circuit occurs. The constant current control is performed during the third arc period $Ta3$. As shown in (B) of Fig. 2, a predetermined third arc current $Ia3$ determined by the third arc current setting signal $Ia3r$ in Fig. 1 is applied. As shown in (C) of Fig. 2, the welding voltage V_w is a value determined by the current value and the arc load. For example, the third arc current $Ia3$ is set to be 60 A. The third arc period $Ta3$ is not a predetermined value, and is about 1 ms to 2 ms.

[0063] Hereinafter, the operational effects of the first embodiment will be described. According to the first embodiment, the arc period is mainly divided into three periods, i.e., the first arc period $Ta1$ during which the first arc current $Ia1$ is applied, the second arc period $Ta2$ dur-

ing which the second arc current $Ia2$ is applied, and a third arc period $Ta3$ during which the third arc current $Ia3$ is applied, and the output control is performed. $Ia1 > Ia2 > Ia3$.

(1) When the first arc current $Ia1$ is set to a large current value, the heat input to the molten pool is increased, the discharge of zinc vapor from the molten pool is promoted, and thus good penetration is ensured. Therefore, the respective values of the first arc period $Ta1$ and/or the first arc current $Ia1$ are set so that the zinc vapor does not remain in the molten pool after being discharged from the molten pool.

(2) When the second arc current $Ia2$ is set to be smaller than the first arc current $Ia1$, explosive ejection of the zinc vapor from the molten pool is suppressed and the welding state is stabilized. The second arc current $Ia2$ is a current value capable of alleviating the generation of the zinc vapor.

(3) When the third arc current $Ia3$ is set to a smaller current value, the melting of the welding wire is suppressed, leading to a short circuit. Accordingly, the cycle of repeating the short circuit period and the arc period is stabilized and the welding state is stabilized. The third arc current $Ia3$ is set to a small current value to the extent that the welding wire does not melt.

[0064] Further, it is desirable that the constant voltage control is performed during the second arc period $Ta2$. By performing the constant voltage control during the period, the arc length can be maintained at an appropriate value, and the welding state can be stabilized.

[0065] Further, it is desirable that the constant current control is performed during the first arc period $Ta1$. When the constant current control is performed, the value of the first arc current $Ia1$ becomes a predetermined value regardless of the arc load. Thus, the amount of heat input to the molten pool during this period can be controlled to a desired value. As a result, discharge of the zinc vapor can be promoted by appropriate heat input. When the heat input amount in this period is excessive, the average value of the second arc current $Ia2$ during the second arc period $Ta2$ is lowered, leading to deterioration in the bead appearance. Therefore, it is important to optimize the heat input during this period.

[Second Embodiment]

[0066] In the invention according to the second embodiment, a value of the first arc period $Ta1$ and/or the first arc current $Ia1$ changes according to a zinc deposition amount per unit area of the base material.

[0067] Fig. 3 is a block diagram of a welding power source for performing an arc welding control method according to the second embodiment of the present invention. Fig. 3 corresponds to Fig. 1 described above, in which the same reference numerals are attached to the

same blocks, and description thereof will not be repeated. In Fig. 3, a zinc deposition amount setting circuit ZR is added as compared with Fig. 1, a first arc period setting circuit TA1R of Fig. 1 is replaced by a corrected first arc period setting circuit TA1R, and the first arc current setting circuit IA1R in Fig. 1 is replaced by a corrected first arc current setting circuit IA1R. Hereinafter, the blocks will be described below with reference to Fig. 3.

[0068] The zinc deposition amount setting circuit ZR outputs a zinc deposition amount setting signal Zr correlated with the zinc deposition amount per unit area of the base material. For example, the zinc deposition amount setting signal Zr is a signal for outputting a positive value of 1 to 5 corresponding to the position of a knob provided on a front panel of the welding power source. The standard value is 3. When a welding worker determines that the zinc deposition amount of the base metal is large, the knob is adjusted to adjust the standard value to 4 or 5. In contrast, when the welding worker determines that the zinc deposition amount of the base metal is small, the standard value is adjusted to 1 or 2.

[0069] The corrected first arc period setting circuit TA1R receives the zinc deposition amount setting signal Zr as an input and increases the value of the first arc period setting signal Talr as the value of the zinc deposition amount setting signal Zr increases, and outputs the increased value.

[0070] The corrected first arc current setting circuit IA1R receives the zinc deposition amount setting signal Zr as an input and increases the value of the first arc current setting signal Ia1r as the value of the zinc deposition amount setting signal Zr increases, and outputs the increased value.

[0071] Since the timing chart showing the arc welding control method according to the second embodiment of the present invention is similar to that of the above-recited Fig. 2, the description thereof will not be repeated. However, the point that the value of the first arc period Ta1 and/or the first arc current Ia1 changes according to the value of the zinc deposition amount setting signal Zr is different.

[0072] According to the second embodiment, the value of the first arc period and/or the first arc current Ia1 changes according to the zinc deposition amount per unit area of the base material. Accordingly, the amount of heat input to the molten pool during the first arc period can be optimized according to the zinc deposition amount of the base material. Thus, the discharge effect of the zinc vapor can be optimized according to the zinc deposition amount.

[Third Embodiment]

[0073] In the invention according to a third embodiment, the waveform parameter of the feed speed is set so that the average value of the repetition frequency of the forward feed period and the reverse feed period is in the range of 70 Hz to 90 Hz.

[0074] Fig. 4 is a block diagram of a welding power source for performing an arc welding control method according to the third embodiment of the present invention. Fig. 4 corresponds to Fig. 3 described above, in which the same reference numerals are attached to the same blocks, and description thereof will not be repeated. In Fig. 4, the forward feed peak value setting circuit WSR and the reverse feed peak value setting circuit WRR in Fig. 3 are deleted, and a forward/reverse feed peak value setting circuit WR is added. Hereinafter, the block will be described below with reference to Fig. 4.

[0075] The forward/reverse feed peak value setting circuit WR outputs a forward feed peak value setting signal Wsr and a reverse feed peak value setting signal Wrr calculated by a predetermined function to which the zinc deposition amount setting signal Zr is input. In this function, the values of the forward feed peak value setting signal Wsr and the reverse feed peak value setting signal Wrr decrease as the value of the zinc deposition amount setting signal Zr increases. This function is set so that the average value of the repetition frequency between the forward feed period and the reverse feed period of the feed speed Fw is in the range from 70 Hz to 90 Hz. More preferably, this function is set so that the frequency is in the range from 75 Hz to 85 Hz. Since the values of the forward feed peak value setting signal Wsr and the reverse feed peak value setting signal Wrr decrease as the value of the zinc deposition amount setting signal Zr increases, the frequency changes so as to be low within the above range.

[0076] Since the timing chart showing the arc welding control method according to the third embodiment of the present invention is similar to that of Fig. 2, the description thereof will not be repeated. However, the following points are different. According to the third embodiment, the waveform parameter of the feed speed is set so that the average value of the repetition frequency of the forward feed period and the reverse feed period of the feed speed is in the range of 70 Hz to 90 Hz. The waveform parameters of the feed speed are at least the forward feed peak value and the reverse feed peak value. When the frequency is smaller than 70 Hz, the heat input to the base material during the arc period is excessive and the ejection of the zinc vapor is severe. As a result, the welding state is unstable, and the spatter generation amount also increases. When the frequency is more than 90 Hz, the arc period is shortened and it is difficult to secure the third arc period. As a result, the spatter generation amount increases and the welding state also deteriorates. When the frequency is in the range from 75 Hz to 85 Hz, the welding state is further stabilized and the spatter generation amount is further reduced.

[0077] Further, the waveform parameter is set so that the average value of the frequency is lowered as the zinc deposition amount per unit area of the galvanized steel sheet increases. Since the ejection of zinc vapor is severe as the zinc deposition amount of the base material increases, the welding state is stabilized by making the

average value of the frequency low within the above range.

Industrial Applicability

[0078] According to the present invention, an arc welding control method can be provided, which is capable of stabilizing the welding state and reducing the spatter generation amount in arc welding in which the material of a base material is a galvanized steel sheet and the feed speed of the welding wire is alternately switched between the forward feed period and the reverse feed period.

[0079] Although the present invention has been described with reference to specific embodiments, the present invention is not limited to this embodiment, and various modifications are possible without departing from the technical concept of the disclosed invention.

[0080] This application is based on a Japanese patent application (Japanese Patent Application No. 2016-213269) filed on October 31, 2016 and a Japanese patent application (Japanese Patent Application No. 2016-232039) filed on November 30, 2016, the contents of which are incorporated herein by reference.

Description of Reference Numerals

[0081]

1.	Welding wire
2.	Base material
3.	Arc
4.	Welding torch
5.	Feed roll
CM	Current comparison circuit
Cm	Current comparison signal
DR	Drive circuit
Dr	Drive signal
E	Output voltage
Ea	Error amplification signal
ED	Output voltage detection circuit
Ed	Output voltage detection signal
EI	Current error amplification circuit
Ei	Current error amplification signal
ER	Output voltage setting circuit
Er	Output voltage setting signal
EV	Voltage error amplification circuit
Ev	Voltage error amplification signal
FC	Feed control circuit
Fc	Feed control signal
FR	Feed speed setting circuit
Fr	Feed speed setting signal
Fw	Feed speed
Ia1	First arc current
IA1R	(Corrected) first arc current setting circuit
Ia1r	First arc current setting signal
Ia2	Second arc current
Ia3	Third arc current
IA3R	(Corrected) third arc current setting circuit

Ia3r	Third arc current setting signal
ICR	Current control setting circuit
Icr	Current control setting signal
ID	Current detection circuit
5 Id	Current detection signal
ILR	Low level current setting circuit
Ilr	Low level current setting signal
Iw	Welding current
ND	Constriction detection circuit
10 Nd	Constriction detection signal
PM	Power source main circuit
R	Current-limiting resistor
SD	Short circuit determination circuit
Sd	Short circuit determination signal
15 STA1	First arc period circuit
Sta1	First arc period signal
STA3	Third arc period circuit
Sta3	Third arc period signal
SW	Power source characteristic switching circuit
20 Ta1	First arc period
TA1R	(Corrected) first arc period setting circuit
Ta1r	First arc period setting signal
Ta2	Second arc period
Ta3	Third arc period
25 Tc	Delay period
Td	Current drop time
TR	Transistor
Trd	Reverse feed deceleration period
TRDR	Reverse feed deceleration period setting circuit
30 Trdr	Reverse feed deceleration period setting signal
Trp	Reverse feed peak period
Tru	Reverse feed acceleration period
35 TRUR	Reverse feed acceleration period setting circuit
Trur	Reverse feed acceleration period setting signal
Tsd	Forward feed deceleration period
40 TSDR	Forward feed deceleration period setting circuit
Tsdr	Forward feed deceleration period setting signal
Tsp	Forward feed peak period
45 Tsu	Forward feed acceleration period
TSUR	Forward feed acceleration period setting circuit
Tsur	Forward feed acceleration period setting signal
VD	Voltage detection circuit
Vd	Voltage detection signal
50 Vw	Welding voltage
WL	Reactor
WM	Feed motor
WR	Forward/reverse feed peak value setting circuit
Wrp	Reverse feed peak value
55 WRR	Reverse feed peak value setting circuit
Wrr	Reverse feed peak value setting signal
Wsp	Forward feed peak value
WSR	Forward feed peak value setting circuit

Wsr Forward feed peak value setting signal
 ZR Zinc deposition amount setting circuit
 Zr Zinc deposition amount setting signal

5

Claims

1. An arc welding control method for controlling welding in which a material of a base material is a galvanized steel sheet, a feed speed of a welding wire is alternately switched between a forward feed period and a reverse feed period, and a short circuit period and an arc period are repeated, wherein during the arc period, a first arc period during which a first arc current Ia1 is applied, a second arc period during which a second arc current Ia2 is applied, and a third arc period during which a third arc current Ia3 is applied are switched over time, to control so as to be $Ia1 > Ia2 > Ia3$.
 10
 15
 20
2. The arc welding control method according to claim 1, wherein constant voltage control is performed during the second arc period.
3. The arc welding control method according to claim 1 or 2, wherein constant current control is performed during the first arc period.
 25
4. The arc welding control method according to any one of claims 1 to 3, wherein a value of the first arc period and/or the first arc current is set to a value such that zinc vapor does not remain in a molten pool after being discharged from the molten pool.
 30
5. The arc welding control method according to any one of claims 1 to 4, wherein a value of the first arc period and/or the first arc current Ia1 is changed according to a zinc deposition amount per unit area of the base material.
 35
 40
6. The arc welding control method according to any one of claims 1 to 5, wherein a waveform parameter of the feed speed is set so that an average value of repetition frequencies of the forward feed period and the reverse feed period is in a range of 70 Hz to 90 Hz.
 45
7. The arc welding control method according to claim 6, wherein the waveform parameter is at least a forward feed peak value and a reverse feed peak value.
 50
8. The arc welding control method according to claim 6 or 7, wherein the waveform parameter is set so that the average value of the repetition frequencies lowers as the zinc deposition amount per unit area of the base material increases.
 55

FIG. 1

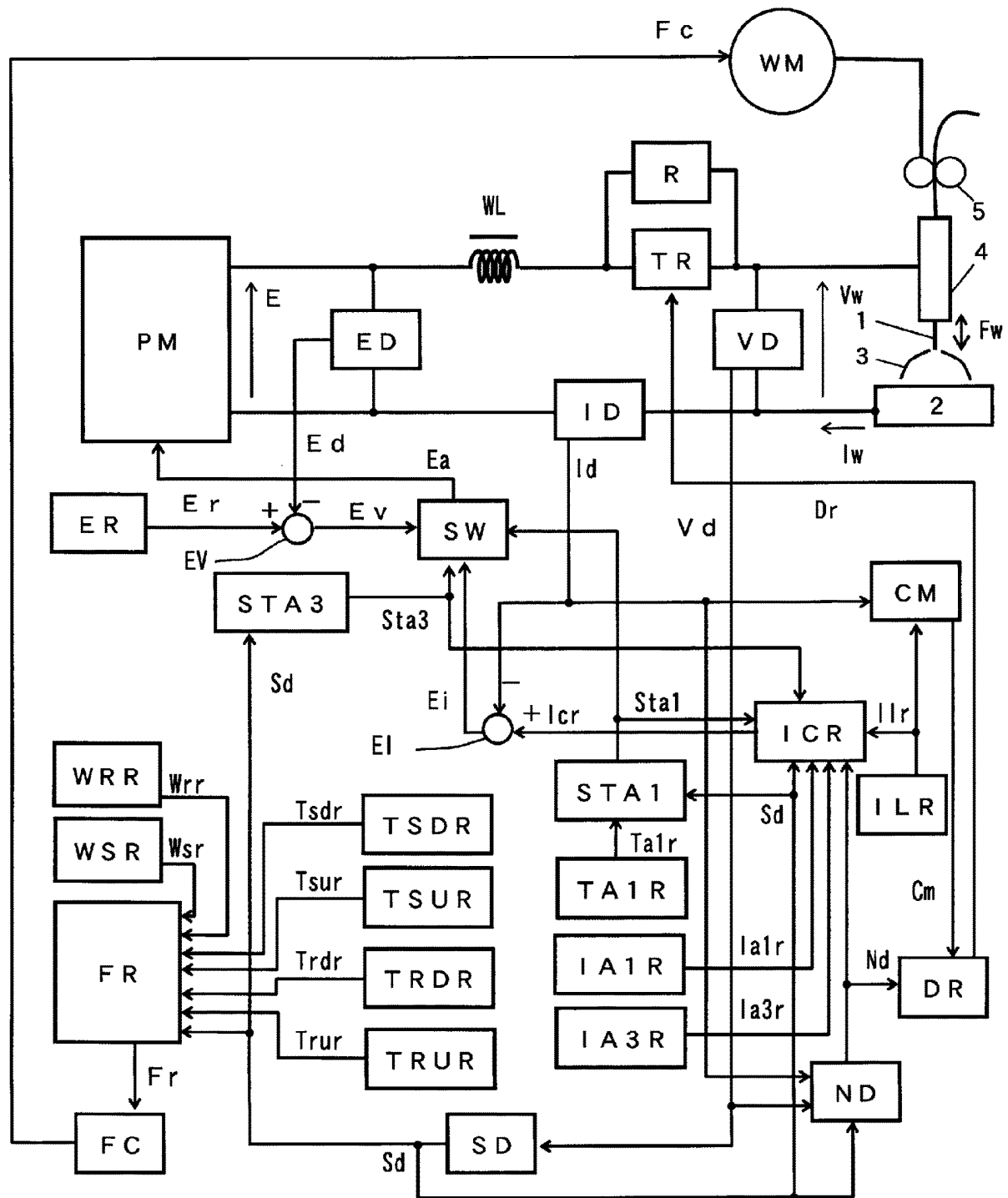


FIG. 2

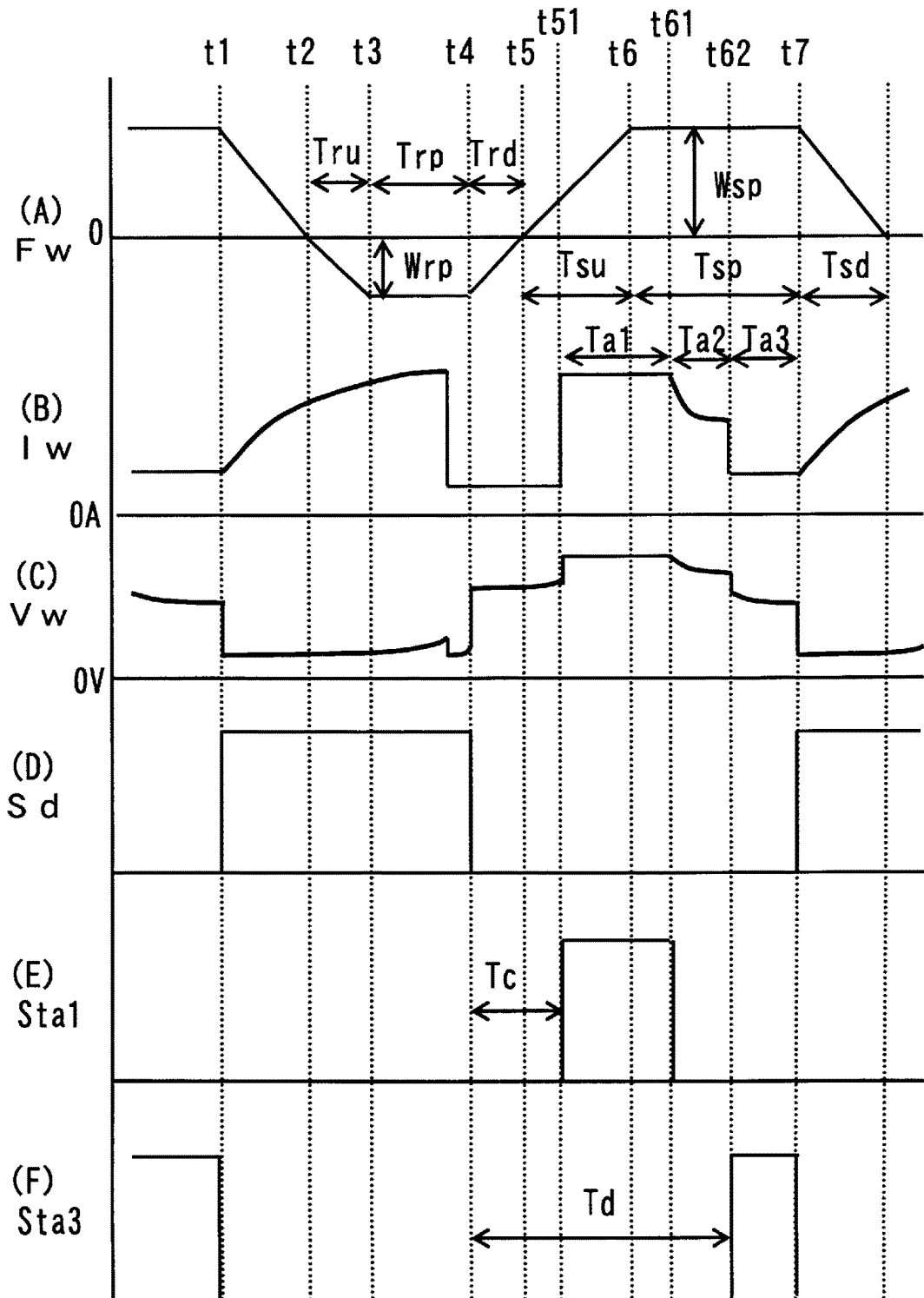


FIG. 3

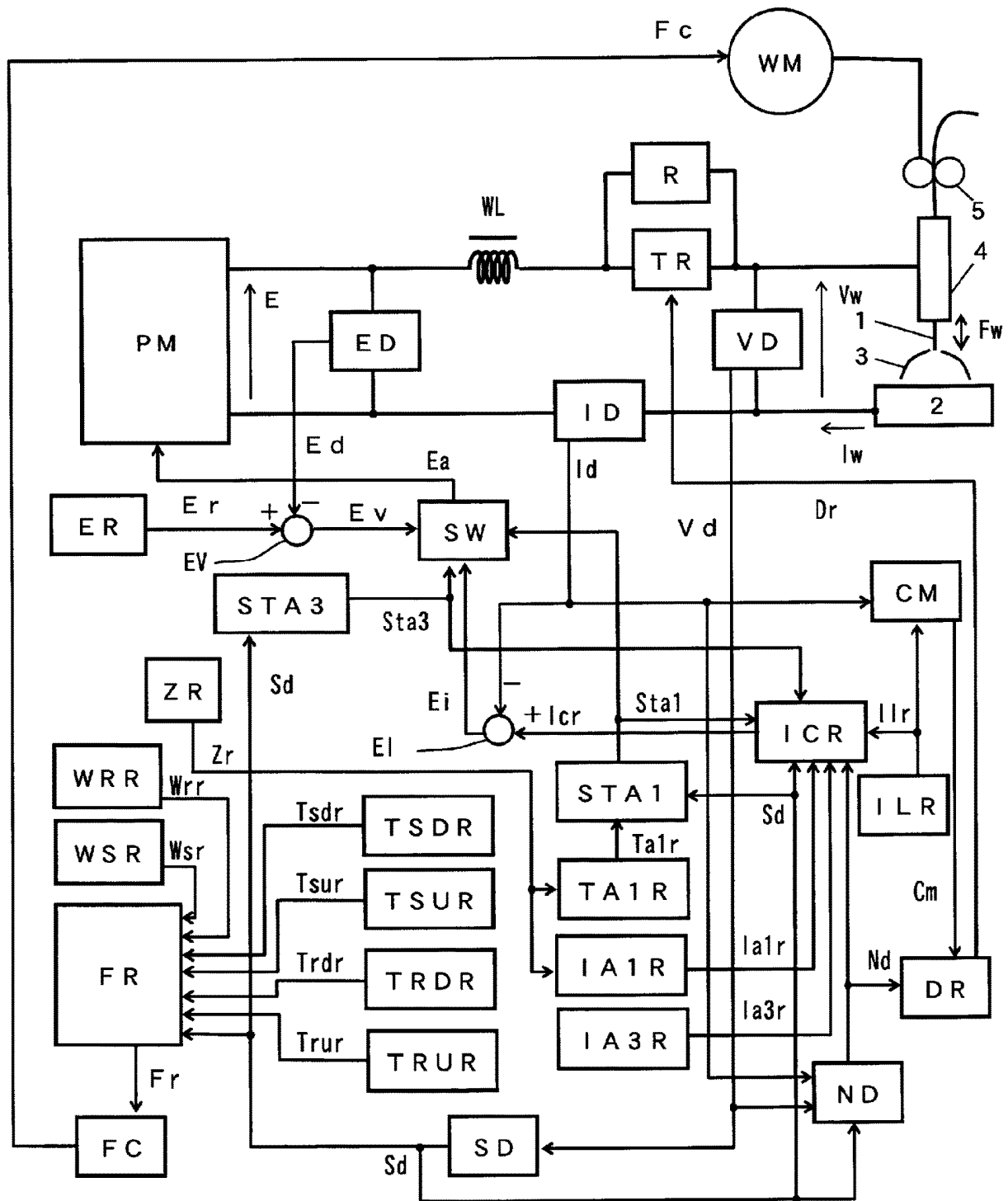
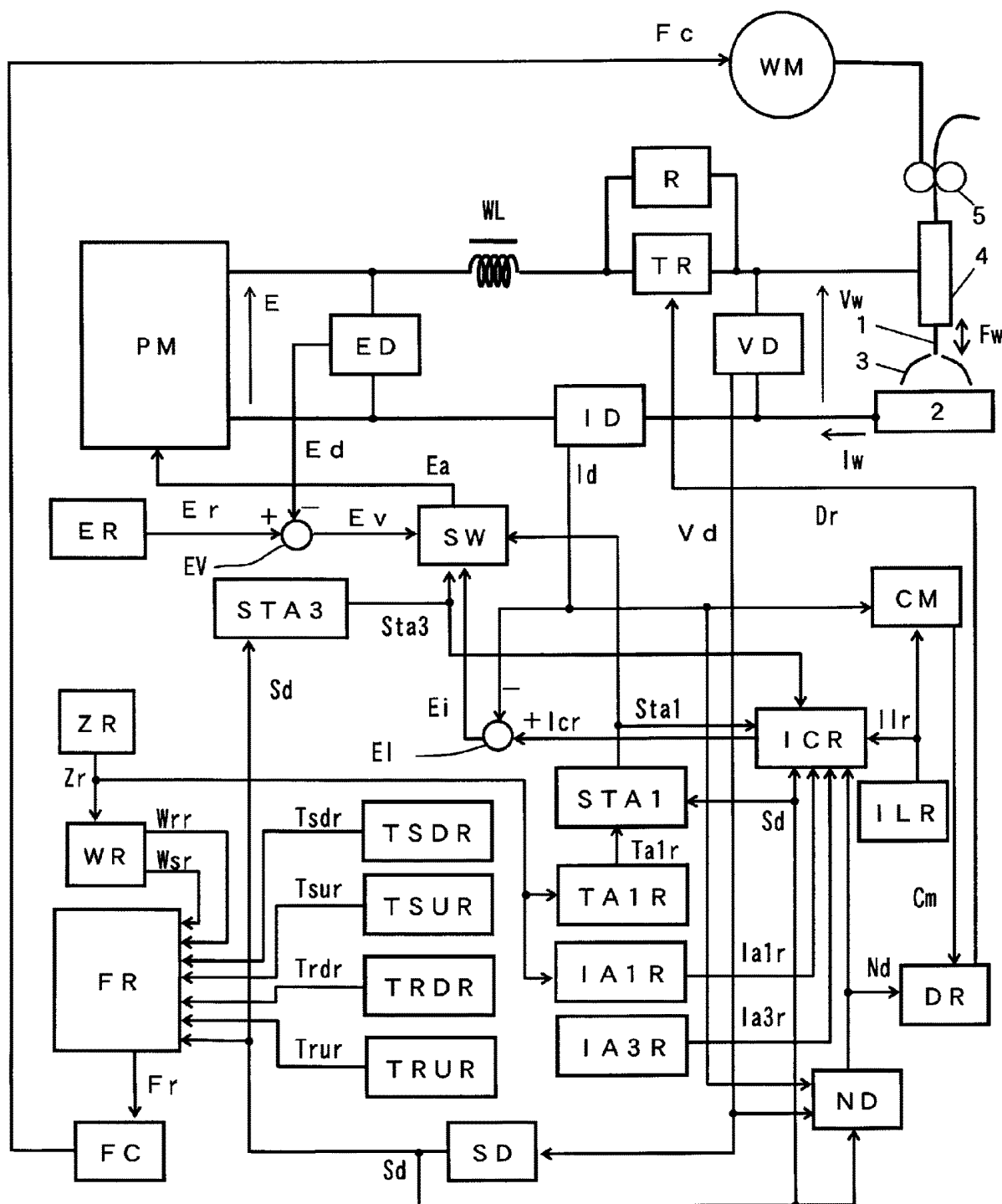


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/035341

A. CLASSIFICATION OF SUBJECT MATTER

B23K9/23(2006.01)i, B23K9/073(2006.01)i, B23K9/12(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23K9/23, B23K9/073, B23K9/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017

Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2013/132550 A1 (Panasonic Corp.), 12 September 2013 (12.09.2013), paragraphs [0014] to [0050]; fig. 2, 5 & US 2014/0202993 A1 paragraphs [0024] to [0060]; fig. 2, 5 & EP 2823926 A1 & CN 103930231 A	1, 3-7 2, 8
Y	JP 61-253175 A (Matsushita Electric Industrial Co., Ltd.), 11 November 1986 (11.11.1986), page 3, upper right column to page 4, upper left column; fig. 2 (Family: none)	1, 3-7

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
30 October 2017 (30.10.17)Date of mailing of the international search report
14 November 2017 (14.11.17)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/035341

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2001-121262 A (Daido Steel Co., Ltd.), 08 May 2001 (08.05.2001), paragraphs [0012] to [0031] (Family: none)	5
A	WO 2014/054261 A1 (Panasonic Corp.), 10 April 2014 (10.04.2014), entire text; all drawings & US 2015/0096965 A1 & EP 2905102 A1 & CN 104602847 A & CN 106392264 A	1-8

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2016213269 A [0080]
- JP 2016232039 A [0080]